Assessment of a New Method for Estimating Density of Suspended Particles

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LONG-TERM GOALS

The goal of the proposed work is to investigate the accuracy of a new method for estimating the bulk density of suspended particles in situ and non-invasively. The new method uses the commercially available LISST-100x particle size analyzer paired with a digital floc camera. It would enable collection of high temporal resolution estimates of particle bulk density.

OBJECTIVES

The research has three objectives:

1. Use existing archived field data from a variety of studies to compare the two methods for estimating particle bulk density.

2. Carry out laboratory studies to assess the accuracy of the two methods in a controlled environment.

3. Gather new field data with which to compare the two methods.

APPROACH

The research compares and contrasts two methods for estimating suspended particle bulk density. An established method uses the size and settling velocity to estimate particle density (e.g., Fennessy et al., 1994; Hill et al., 1998; Hill et al., 2011). With this method Stokes Law (or a modified form for larger Reynolds number particles) is re-arranged to yield particle density according to the following equation:

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$$\rho_s = \frac{18 w_s \mu}{gD^2} + \rho \tag{1}$$

In Equation 1, ρ_s is the particle density (kg m^{-3}), w_s is particle settling velocity (m s^{-1}), μ is the dynamic viscosity of water (kg m^{-1} s^{-1}), g is gravitational acceleration (m s^{-2}), D is particle diameter (m), and ρ is the density of water (kg m^{-3}). The sizes and settling velocities of suspended marine particles are observed with underwater video in a settling column that is closed to the environment during video observations (cf. Hill et al., 2011) and open to the environment during the intervening periods. Median bulk density of particles in suspension are calculated from the population of particles observed in 4 frames separated by 1 s that are extracted from 1-min video clips. This method is accurate but laborious, and it requires specialized, non-commercial instruments.

The proposed new method makes use of a key result of our recent ONR-funded OASIS research. In that work, we demonstrated that optical beam attenuation per unit of suspended particle mass is relatively insensitive to particle size, which renders the particle optical beam attenuation coefficient (c_p) proportional to suspended sediment mass despite the variations in particle size that are typical of coastal waters (Boss et al., 2009; Hill et al., 2011). By extension, the ratio of c_p to suspended particle volume should be proportional to suspended particle density.

The particle optical beam attenuation coefficient is estimated with the Sequoia Scientific LISST- 100x. The particle optical beam attenuation coefficient is equal to the natural log of the ratio of transmitted light intensity in particle-free water to the transmitted light intensity in a suspension divided by the pathlength that the beam traverses between transmitting and receiving optics (cf. Hill et al., 2011).

Particle volume is measured with the LISST 100x and a custom-built Digital Floc Camera (DFC). The LISST estimates particle volumes for particles with diameters from ~1.25-250 μm, and the DFC estimates volumes of particles with diameters larger than ~50 μm. Although the DFC is not commercially available, there are new commercial sensors that can provide similar data for large suspended particles. The LISST estimates particle volume by inverting the annular distribution of scattered light from a collimated laser beam. The DFC estimates particle volume by analysis of silhouette, backlit images of particles suspended in a 4 x 4 x 2.5 cm slab of fluid located between the camera housing and flash housing. Particles are identified in DFC images via edge detection, and areas and equivalent spherical volumes are estimated from the outlined particles. The LISST and DFC data are merged to produce a spectrum of particle volumes for diameters from ~1.25-10^4 μm (cf. Hill et al., 2011).

The proportionality coefficient linking the c_p-to-volume ratio to bulk density is determined by collecting water samples at the point and time of instrument deployment. For remote deployments, water samples are filtered in situ with a McLane phytoplankton sampler. This device filters pre-set volumes of fluid through one of 24 individual filters at pre-set times. For work in tanks and shipboard work, water samples are collected with bottles, then filtered in the lab. Mass concentrations are found by dividing the sediment mass on the filter by the volume filtered. The slope of the regression line of c_p on suspended particulate mass (*SPM*) yields the c_p:*SPM* ratio. The c_p-to-volume ratio is converted to a density by dividing by c_p:*SPM*.

The proposed new method offers several potential advances. It is not labor-intensive; it can be carried out with commercially available instruments; and it can provide remote estimates of particle density at

high temporal frequencies. Testing it against the established method is being carried out under this project.

RESULTS

MSc student Alex Hurley has compared the two methods for estimating suspended particle bulk density for the following data sets: OASIS 2007 and 2011; Willapa Bay, 2009; Bay of Fundy Aquaculture site, 2011 and 2012; Minas Basin, 2013. In general the methods provide similar estimates of density. Agreement degrades as median particle sizes decrease. Alex is exploring the hypothesis that the video method is biased to large particles, so when particles in suspension are on average significantly smaller than the lower size limit of the video camera, density estimates from this method will be low. Larger particles have lower densities because they are flocculated.

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HONORS/AWARDS/PRIZES

Paul Hill, Award for Excellence in Teaching, Faculty of Science, Dalhousie University